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March 31, 2015

Ms. Michele Dermer  
EPA Region 9, WTR-9  
75 Hawthorne St.  
San Francisco, CA 94105

**Subject: Request to Provide Remedial Cementing Plan  
PG&E Test Injection/Withdrawal Well 1  
Permit No. R9UIC-CA5-FY13-1  
King Island, San Joaquin County, California**

Dear Ms. Dermer:

EPA's letter to PG&E dated February 9, 2015 providing authorization to inject into PG&E Test Injection/Withdrawal Well 1 included comments regarding the cement bond log interpretation in the Well Completion Report dated January 29, 2015. The EPA letter stated: *"The quality of the cement bonding is sufficient to provide adequate isolation of USDWs above 3,840 feet from the injection zone and injected fluids. However, the cement bond above 3,785 feet varies from good to poor, and must be addressed."* Based on their concerns regarding the cement bond above 3,785 feet and the potential for migration of oxygen-depleted air and ambient air through micro-annulus, EPA directed PG&E to submit a proposed procedure for a remedial cementing operation within 30 days of the receipt of the February 9, 2015 letter (by March 11, 2015).

In a conference call with PG&E on February 19, 2015, EPA clarified their comments and requirements regarding remedial cementing provided in their February 9, 2015 letter. In the call, EPA stated their concern that the "good to poor" cement bond from the surface casing shoe at 630 feet to the defined top of USDW at 3,840 feet might allow formation fluid to migrate from higher salinity USDW zones to lower salinity USDW zones across certain unspecified intervals.

Subsequent to the February 19, 2015 call with EPA, PG&E initiated an evaluation of open-hole geophysical logs to estimate the salinity of USDW zones, and a re-evaluation of the cement bond log over the 9-5/8 inch casing over specific intervals between 630 and 3,840 feet. Additional time was required to conduct these evaluations; accordingly, PG&E requested, and EPA granted, an extension to March 31, 2015 to submit a procedure for remedial cementing. The results of the open-hole and cased-hole log analyses performed by Digital Formation and Crescent, respectively, are attached. The results of the Digital Formation salinity evaluation of the USDW

interval (630-3,840 feet) are presented in an interpretation log, and are accompanied by a report describing the evaluation methodology (based on the Archie Equation) (Attachment 1). Salinity (NaCl equivalent) was calculated in USDW zones considered capable of flow. The determination of flow zones was based on Spontaneous Potential (SP) curve development (as a permeability indicator), porosity and percent shale volume (Vsh – based on gamma ray log). Calculated salinities within the previously defined USDW interval (630-3,840 feet) range from 5,383 to 15,619 ppm, and are consistent with a higher base of USDW (between 3,265 and 3,527 feet).

Based on the USDW flow zones and salinities identified in the open-hole log analysis, Crescent performed a reevaluation of the CBL for the intervals consisting mostly of shale separating USDW flow zones of different salinity (Attachment 2). Crescent also consulted with other experts in the logging field to gain their perspective of information. Crescent concluded that there is adequate bonding throughout these intervals, and that squeeze operations would pose a high risk of damage to the existing isolation within the wellbore, with a very low probability of improving isolation in the wellbore.

Based on the results of the CBL reevaluation performed by Crescent, PG&E does not propose remedial cementing for the PG&E Test Injection/Withdrawal Well 1. PG&E believes that current cement bond is adequate to prevent fluid migration between USDW zones of different salinity, and that squeeze operations would be much more likely to damage the integrity of the well rather than improve upon the current cement bond.

The Digital Formation log/report and Crescent report are enclosed as hard copies and in electronic format as PDF files on the enclosed data CD. The documents have also been uploaded to PG&E's Dropbox account, which can be accessed at the following link:

[https://www.dropbox.com/sh/4t01bmhvr85k3kv/AAAf4GvjRLC6Wlgq8LYZy\\_7\\_a?dl=0](https://www.dropbox.com/sh/4t01bmhvr85k3kv/AAAf4GvjRLC6Wlgq8LYZy_7_a?dl=0)

If you have any questions regarding this submittal or require additional information, please feel free to contact me at (415) 973-6270.

Sincerely,

A handwritten signature in blue ink, appearing to read "Mike Medeiros".

Mike Medeiros  
Manager, Renewable Energy Development

Cc: Mr. James Walker, EPA Consultant  
Mr. Michael Woods, Division of Oil, Gas and Geothermal Resources  
Ms. Anne L. Olson, Central Valley Regional Water Quality Control Board

Enclosures: (1) Digital Formation Salinity evaluation log and report  
(2) Crescent Cement Bond Log Analysis and Opinion  
(3) Data CD



# **Salinity Analysis of the Upper Section in the PG&E Test Withdrawal- Injection Well 1**

**Prepared for  
MHA Petroleum Consultants**

**By Digital Formation, Inc.  
Denver, Colorado, USA**

**March 2015**

**[www.DigitalFormation.com](http://www.DigitalFormation.com)**



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## Plots

Basic Results with Salinities

## Introduction

In early March 2015, Mark Ausburn contacted Digital Formation with a request for the analysis of the upper section of the PG&E Test Withdrawal-Injection Well 1 from the bottom of the surface casing (~630 ft.) down to the base of Underground Source of Drinking Water (USDW), defined to be around 3840 ft. We were asked to help define USDW flow units (considered likely to have moveable water) and calculate their salinity in order to identify zones for possible remedial cement squeezing to prevent behind casing flow between USDW flow units of different salinity.

## Data Prep

Due to several intervals of significant hole washout conditions, a hole correction was applied to the density log. This correction accounts for the limited volume of actual rock seen by the density tool.

## Analysis

For total porosity the density log was used assuming a sand matrix (2.65 g/cc). This matrix resulted in unrealistically high porosities in the shaley intervals. Thus a variable matrix density model was used to lower Rho matrix in intervals with  $V_{SH}$  greater than 25%, ranging from 2.65 down to 2.2 at 100%  $V_{SH}$ .

To determine the common flow units, an analysis was made to determine the likely salinity throughout the section from surface casing (630 ft.) down to the base of USDW (3840 ft.). This was done using Archie's equation:

$$S_w^n = \frac{a \times R_w}{\phi^m \times R_t}$$

Since this entire section is known to be wet and non-hydrocarbon bearing,  $S_w$  is one, and therefore the equation can be reduced and rearranged to:

$$R_w = \frac{\phi^m \times R_t}{a}$$

The Archie parameter 'a' is generally considered to be one. So using the common value of two for the cementation exponent 'm', the calculated total porosity, and the deep resistivity,  $R_w$  was calculated. Using the Schlumberger Gen-6 chart book,  $R_w$  was converted to a temperature corrected NaCl equivalent salinity for each USDW flow unit.

Sand and sand package intervals were identified from zones with good SP log development, which also suggests higher permeability. For each of these intervals, the average salinity was calculated. The following is a summary:

Interval	Average NaCl Equivalent ppm
883-900 †	5539
945-985 †	5536
1170-1278 *	7885
1320-1370	7666
1395-1430 *	5687
1580-1618	5383
1825-1884	7257
1912-1935	7504
2020-2040 *	8783
2220-2225	8416
2345-2355	7879
2625-2650	7628
2765-2772	6516
2900-3030 * ‡	6210
3085-3195 ‡	7884
3255-3265	9142
3527-3540	13484
3782-3815 ‡	15619

\* Part of the interval is washed out

† The majority of the interval is washed out– logs have been corrected as best as can be done, but the analysis results should be considered suspect

‡ Part of the package of sands have high GR and  $V_{SH}$

These results were all presented on a single log template. To help identify intervals that would be considered likely to have moveable water, the porosity above 35% is highlighted in dark blue. A second, lighter blue shading highlights the same high porosities, but only in clean formation ( $V_{SH} < 25\%$ ). Zones in the  $V_{SH}$  track with  $V_{SH} > 25\%$  are shaded gray. The light blue shaded intervals represent USDW flow units capable of allowing cross-flow if annular cement channels are present.

Time: 01:21 PM

Date: Fri, Mar 27, 2015

Section: 27

Township: 3N

Range: 5E

API #: 077-20739

Location: -121.422161054, 83.081988814

NAD83

UWI: 077-20739

Logging date: 18-Oct-2014

GL: -3.8 ft

Rm: 3.5 ohmm

Rm Temp: 62 degF

degF

KB: 8.3 ft

Rmf: 2.98 ohmm

Rmf Temp: 147 degF

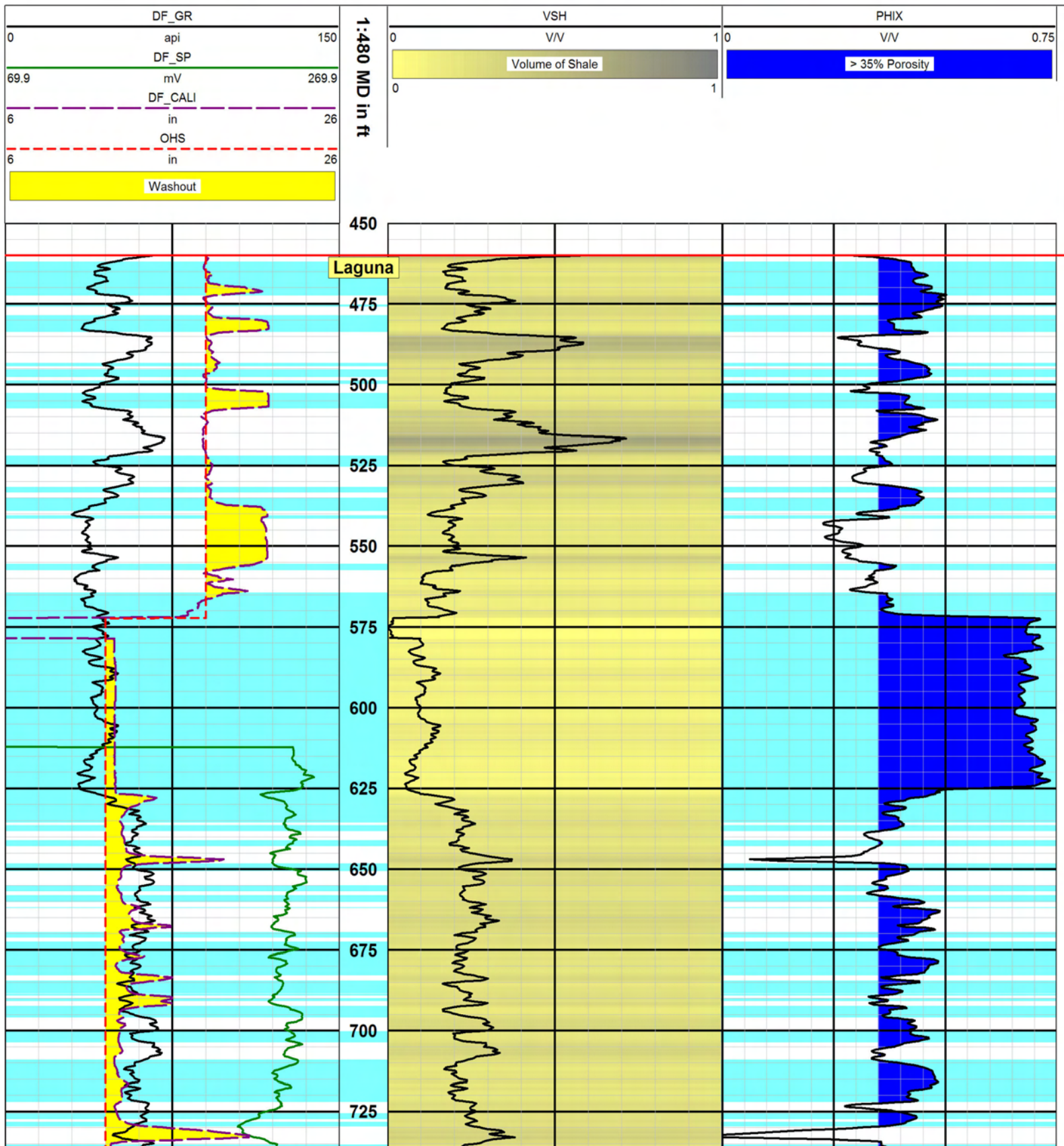
degF

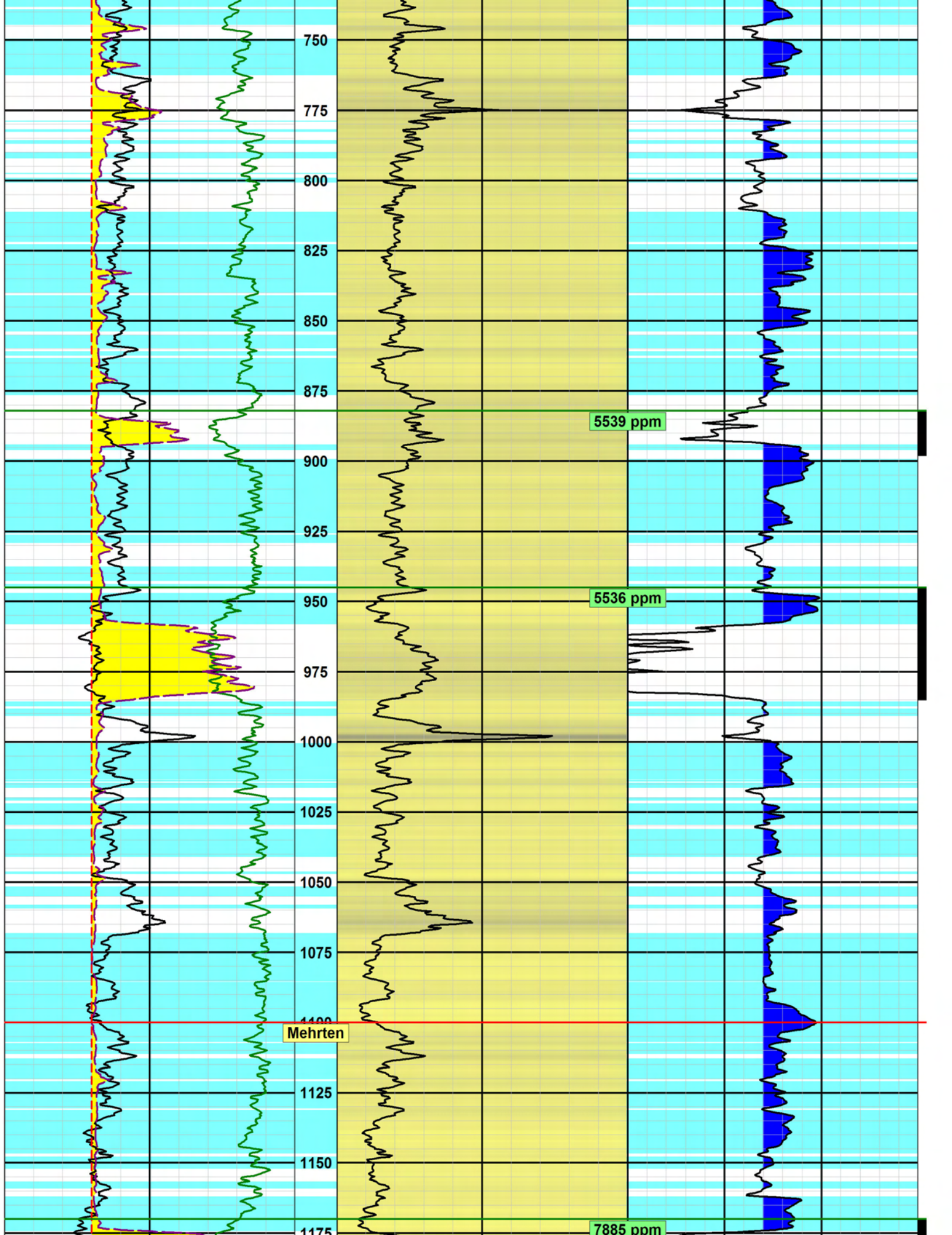
Total Depth: 4963 ft

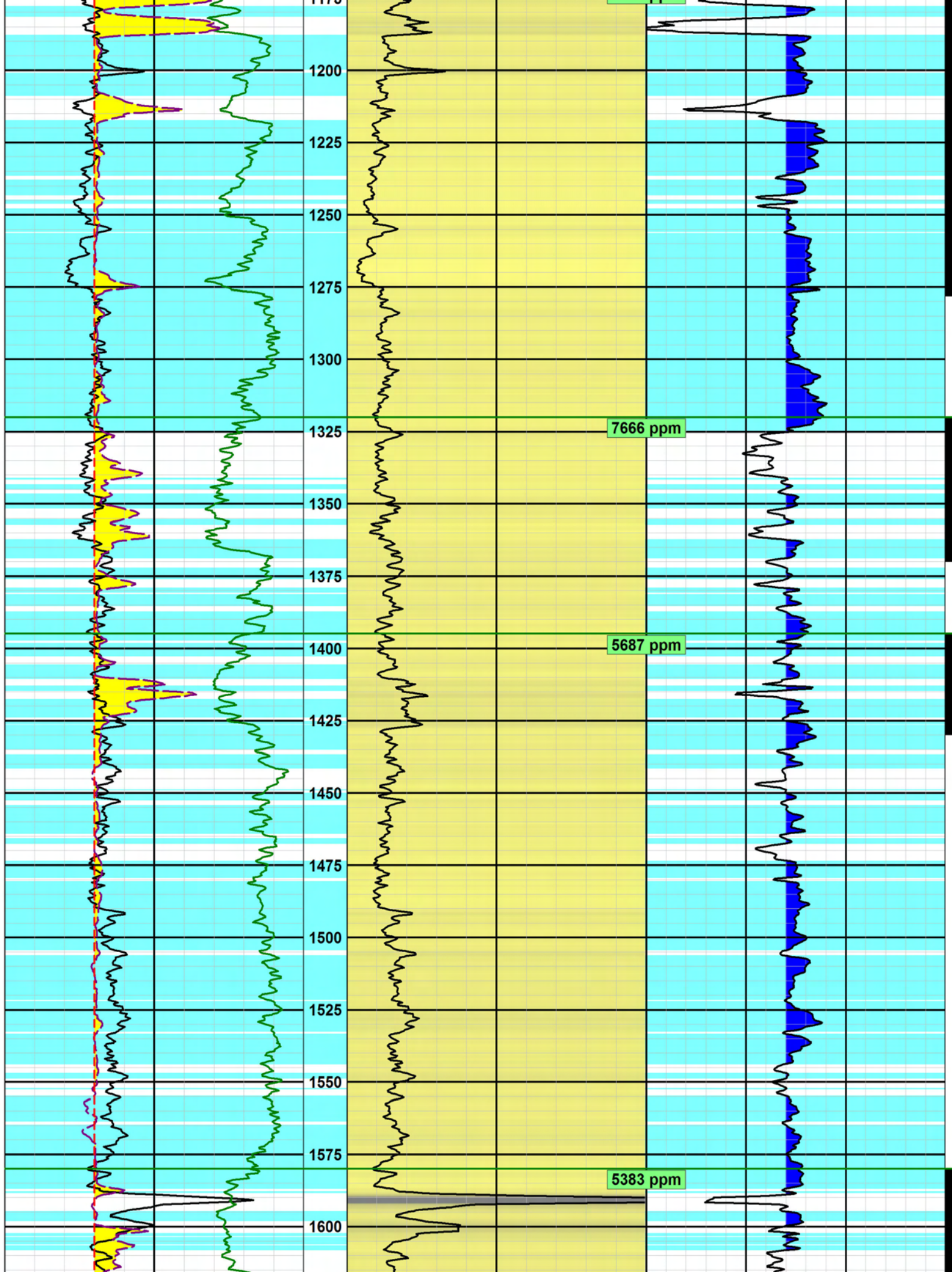
Rm @ BHT: 1.57 ohmm

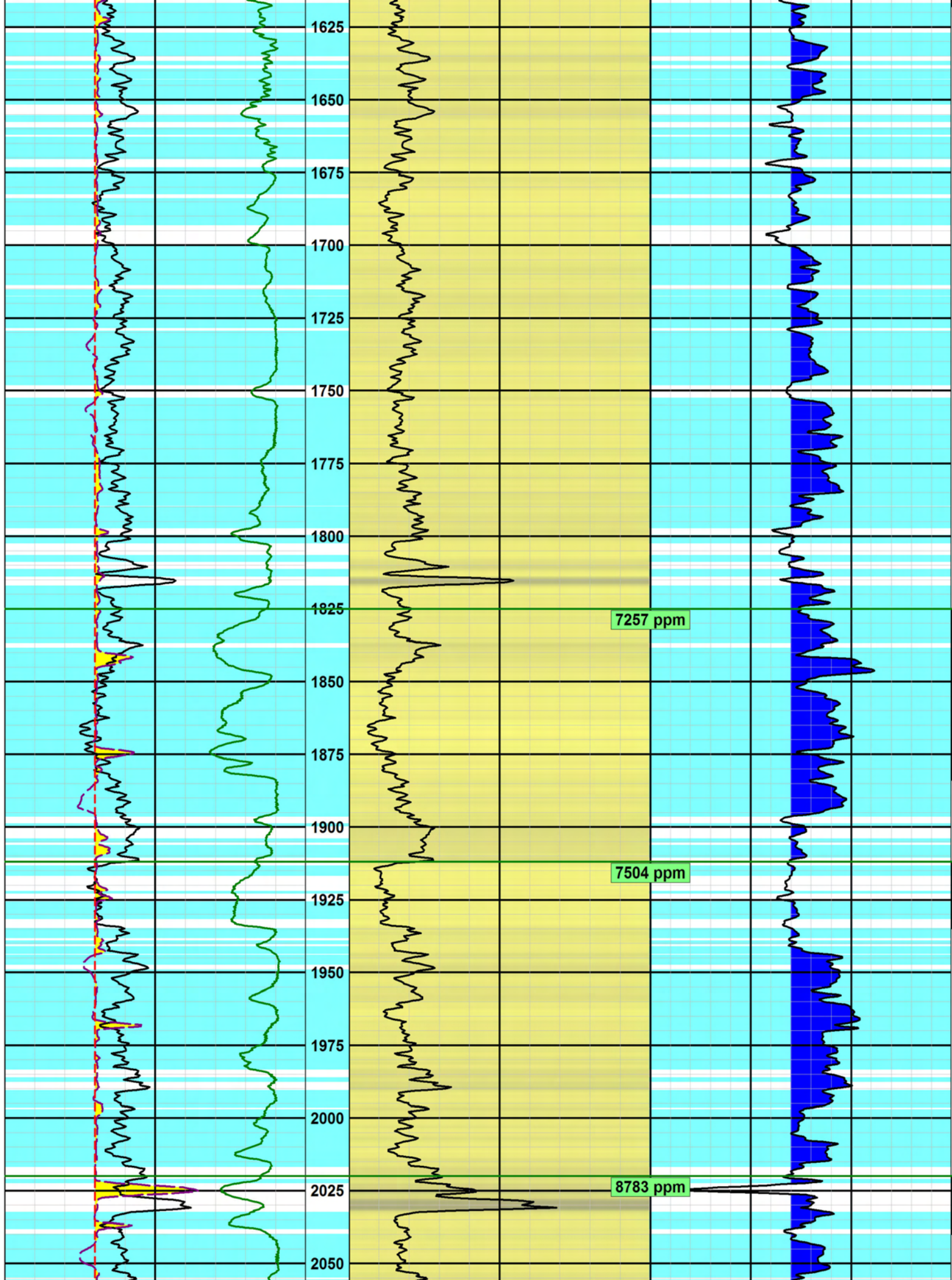
Max Temp: 147 degF

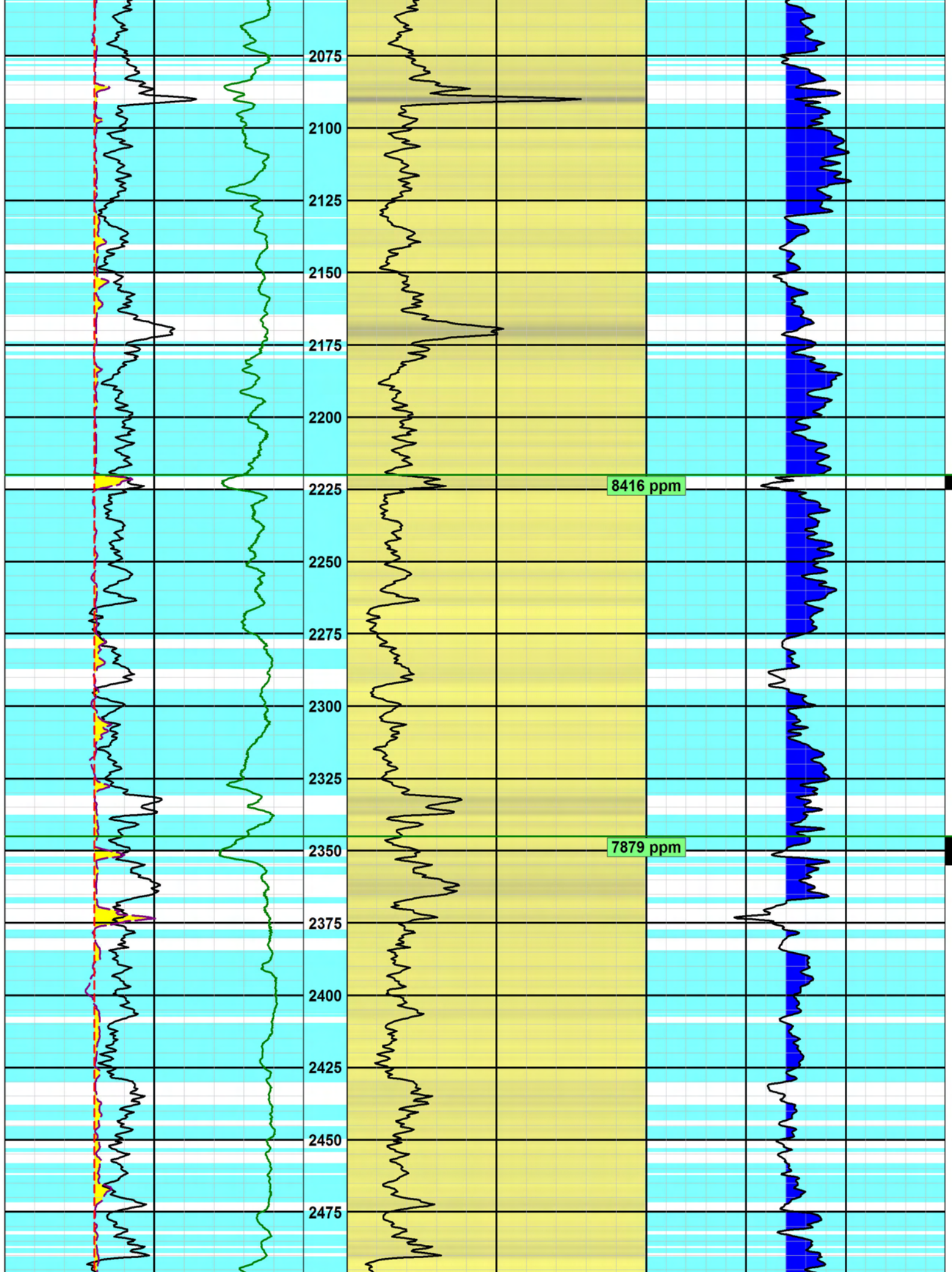
degF

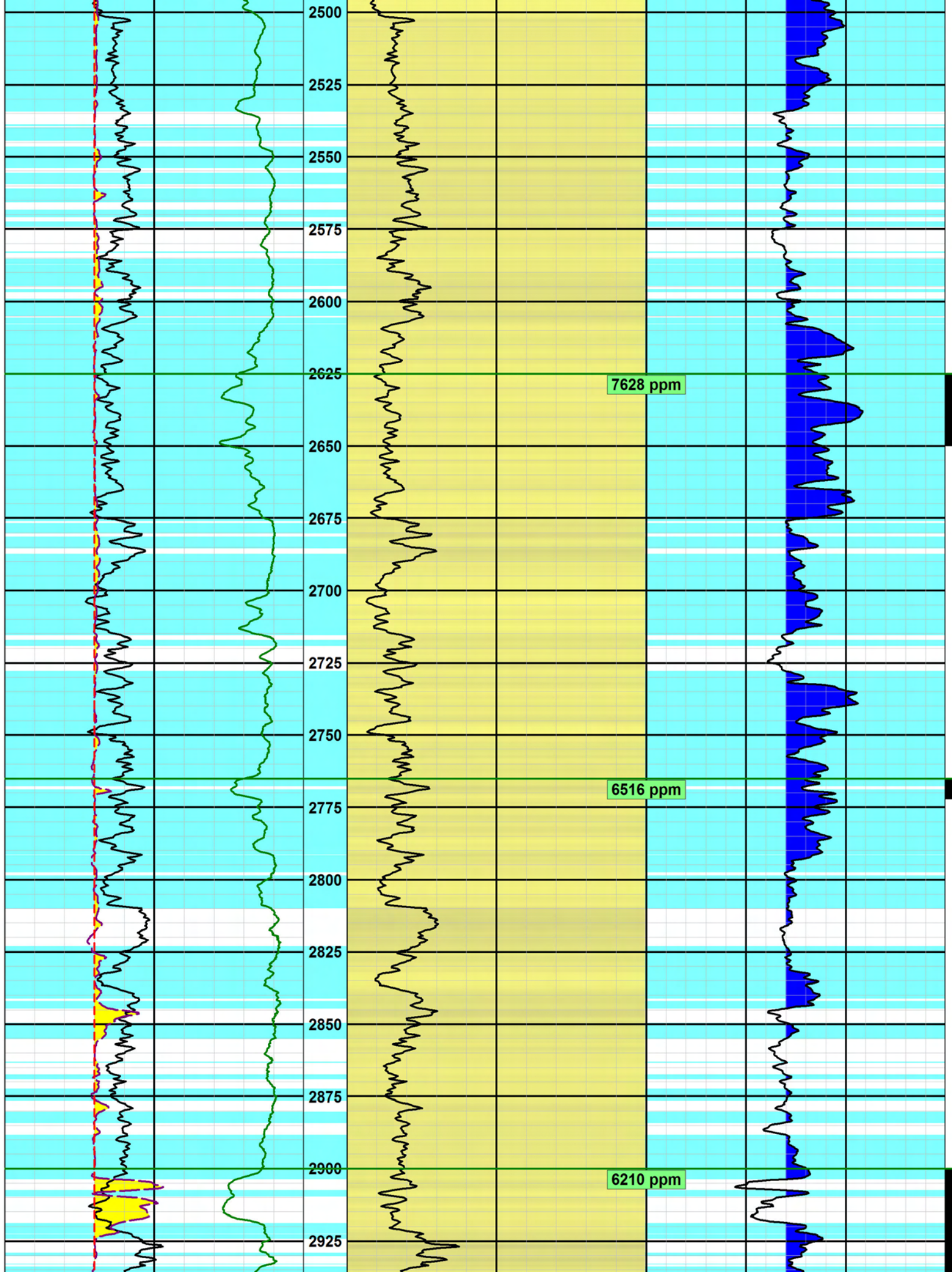


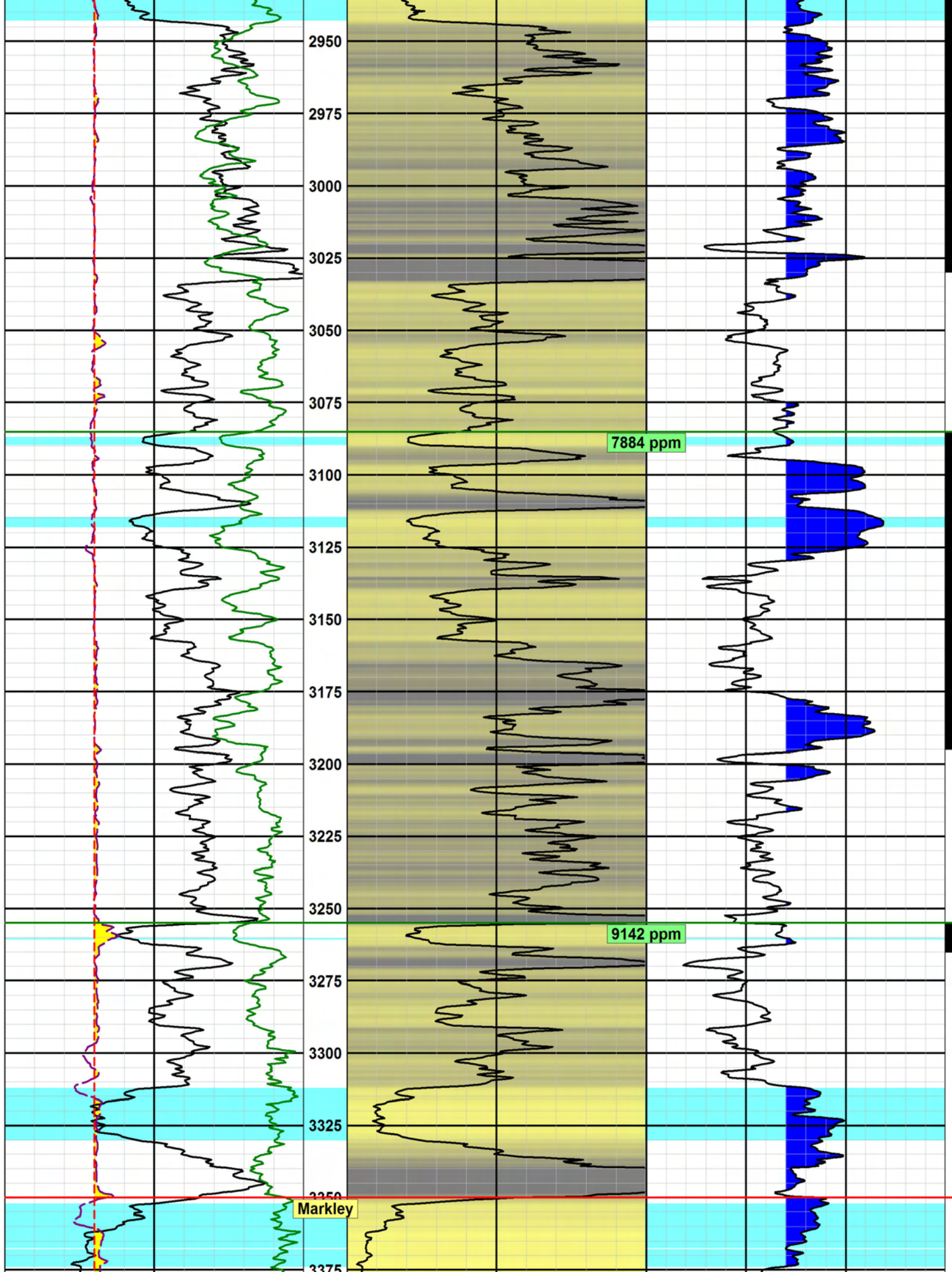


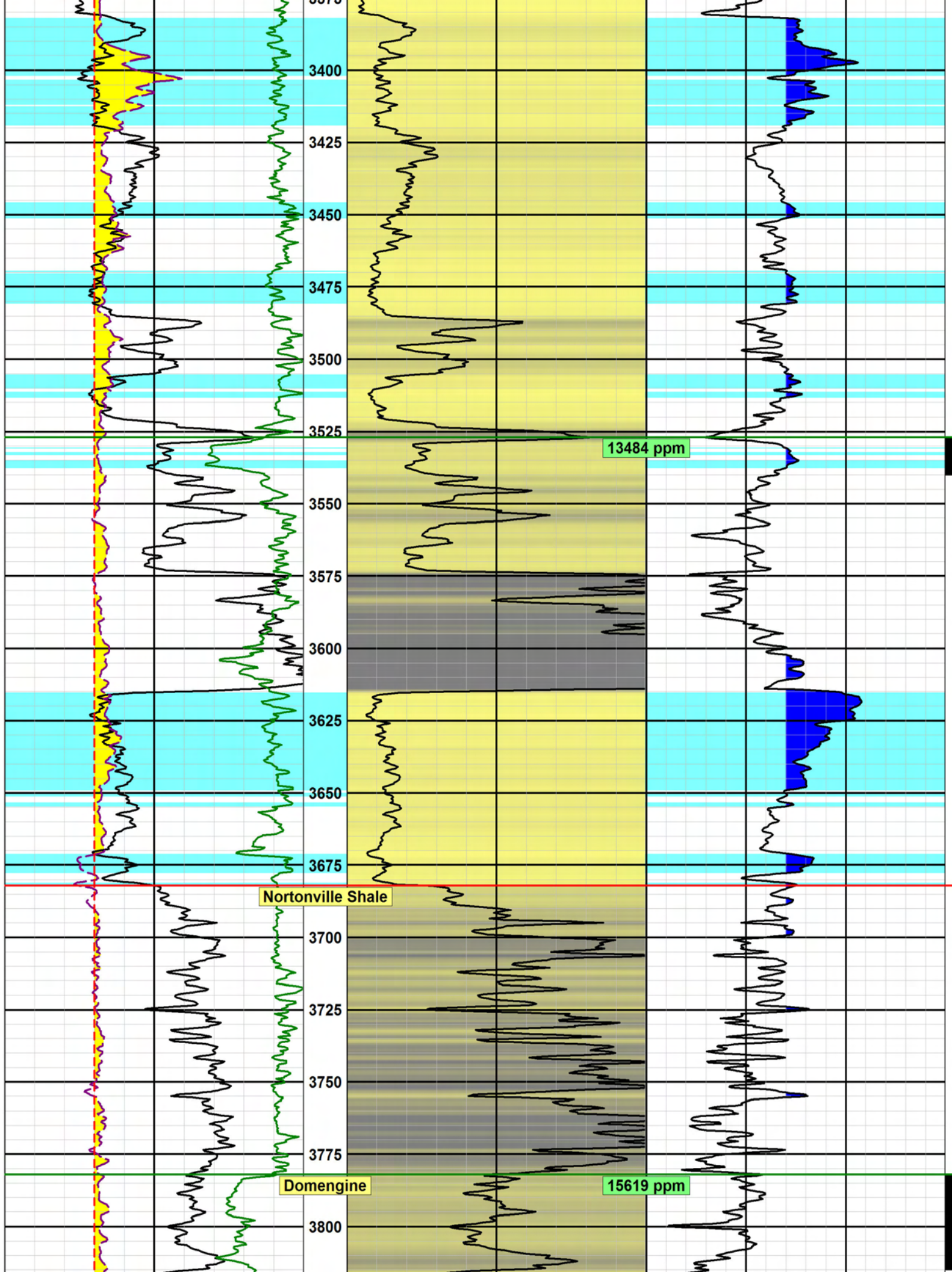


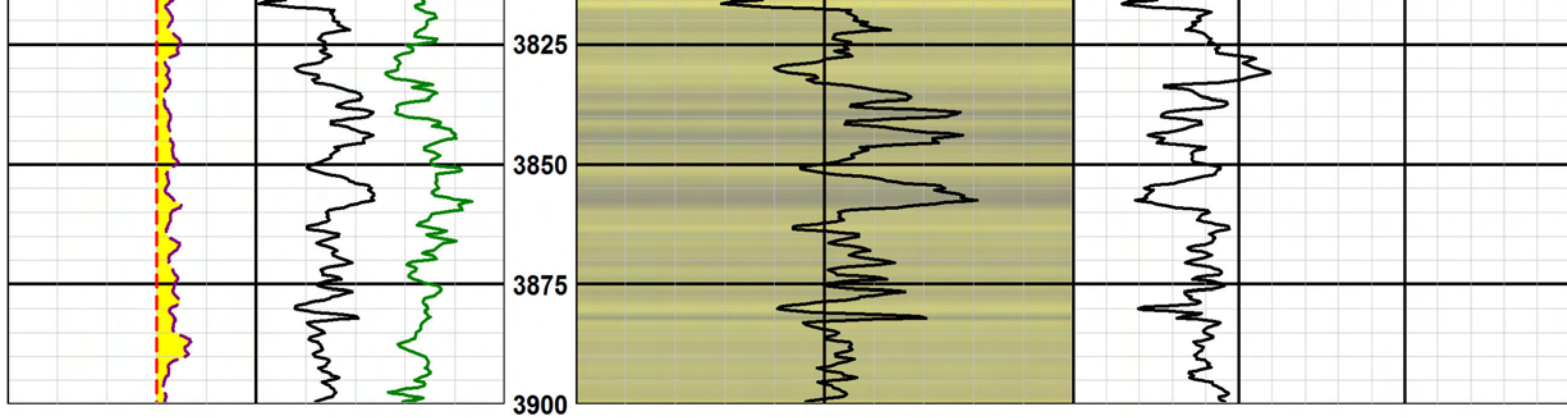












Shawn D. Reed  
VP of Operations and Business Development  
Comprehensive Production Services, LLC  
600 17<sup>th</sup> St. Suite 2800S  
Denver, Co. 80202  
March 30, 2015



Mr. Charlie Stinson, PE  
CS Energy Ventures  
1892 N Birch  
Canby, Or 97013

RE: **PG&E King Island I/W well Cement Bond Log – Analysis and Opinion** - Specific Interval review

Scope of Review

We were asked to review the specific intervals listed below of the Halliburton Energy Services, Radial Cement Bond Log on the 9 5/8" casing string for the PG&E Test Injection/Withdrawal Well in the King Island Gas Field in San Joaquin County, California. The Log was run on the 24<sup>th</sup> of October 2014. The well API # is 04-077-20739.

Selected Intervals

985 – 1170'  
1370 – 1395'  
1618 – 1825'  
1935 – 2020'  
2650 – 2765'  
3030 – 3085'  
3195 – 3255'  
3265 – 3520'



The requested opinion is as follows for each interval:

- 1) Is there adequate cement bond anywhere within the evaluation interval to prevent fluid movement across the interval?
- 2) If not, at what depth would you recommend performing a cement squeeze job?
- 3) Any recommendations regarding the cementing procedure would be appreciated.

As in the original evaluation, I called upon Robert J. Lund of RJL Engineering, Inc. to provide an additional opinion. Bob has over 30 years of related experience directly related to logging operations and interpretation. Bob has extensive knowledge of Halliburton and Schlumberger tools, their use and limitations.

Prepared by  
Shawn D. Reed – CPS, LLC

Robert J. Lund – RJL Engineering, Inc.



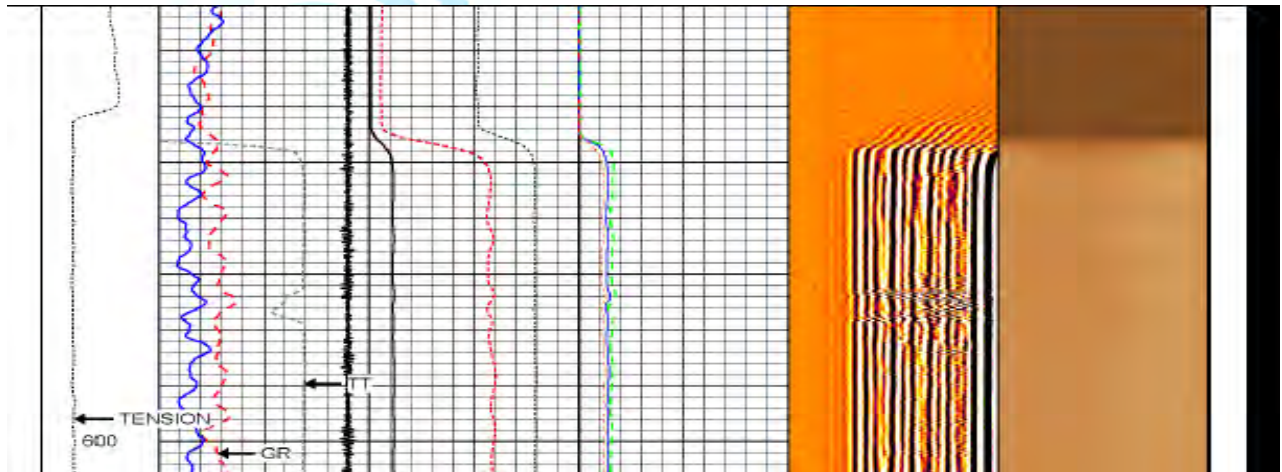
### Selected Intervals - Summary

985 – 1170' - Question 1 – Yes there is adequate isolation throughout the section  
1370 – 1395' - Question 1 – Yes there is adequate isolation throughout the section  
1618 – 1825' - Question 1 – Yes there is adequate isolation throughout the section  
1935 – 2020' - Question 1 – Yes there is adequate isolation throughout the section  
2650 – 2765' - Question 1 – Yes there is adequate isolation throughout the section  
3030 – 3085' - Question 1 – Yes there is adequate isolation throughout the section  
3195 – 3255' - Question 1 – Yes there is adequate isolation throughout the section  
3265 – 3520' - Question 1 – Yes there is adequate isolation throughout the section

In each case we believe strongly that there is adequate bonding throughout these intervals. Consequently, squeeze operations pose a high risk to damage the existing isolation within the wellbore, with a very low probability of improving the isolation in the well.

Analysis of each individual zone follows.

### Additional evidence of Cement Sheath

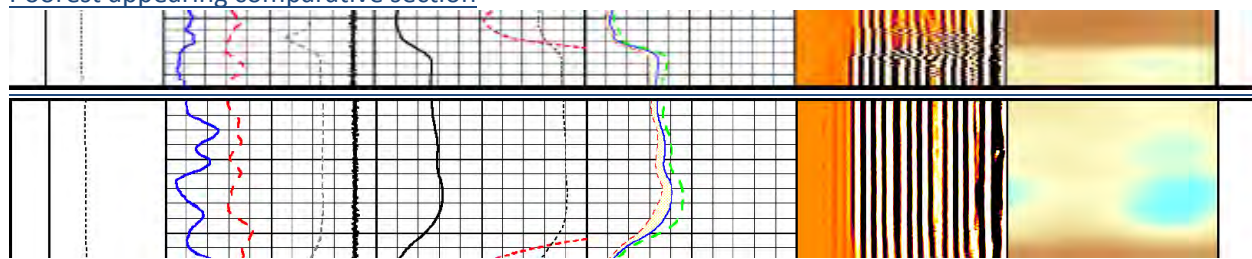


We mentioned that the data was meaningless until fluid was reached in previous correspondences. Note that when the tools reached the fluid, there is immediate formation arrival indicating acoustic coupling. Cement was circulated to surface on the job, and this is solid evidence of the presence of cement sheath.

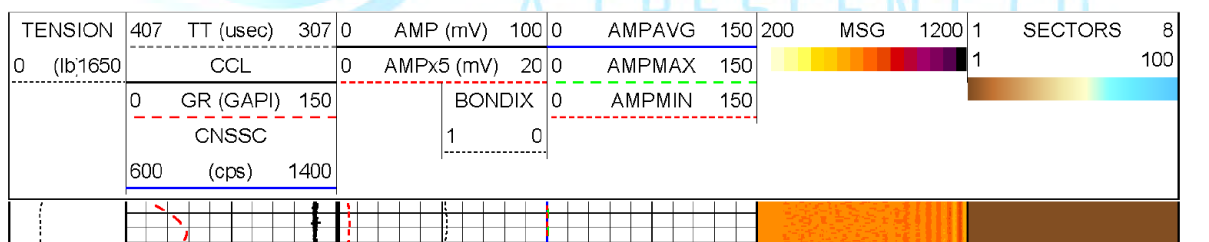
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### Poorest appearing comparative section



In looking throughout the logged interval, this section (950-984') would appear to have the poorest bond signature performance. Note that the amplitude curves are all moving, they are not in a straight line of equal amplitude, as you go from top to bottom. This in itself would indicate that this is categorically **NOT** free pipe. I collaborated with another expert in the logging field, Robert J. Lund, who partnered with me on the original analysis and with my own personal experience we believe this section to be at worst somewhat "bonded". The segmented bond tool pictures multiple sectors of the well, which is why there is an Amplitude max, min and average represented. Note also in this illustration in the 4th track that when the green and red lines separate this is an indication that there are differences between what is being read on the individual receivers. When they all track together the response is consistent at each of the receivers, indicating very similar materials in the sheath. "Free pipe" response is typically 50-51 mV. This level of response indicates the pipe is undamped by solid material behind the pipe. The Track 4 scale is 0mV on the left to 150mV on the right, as illustrated below..

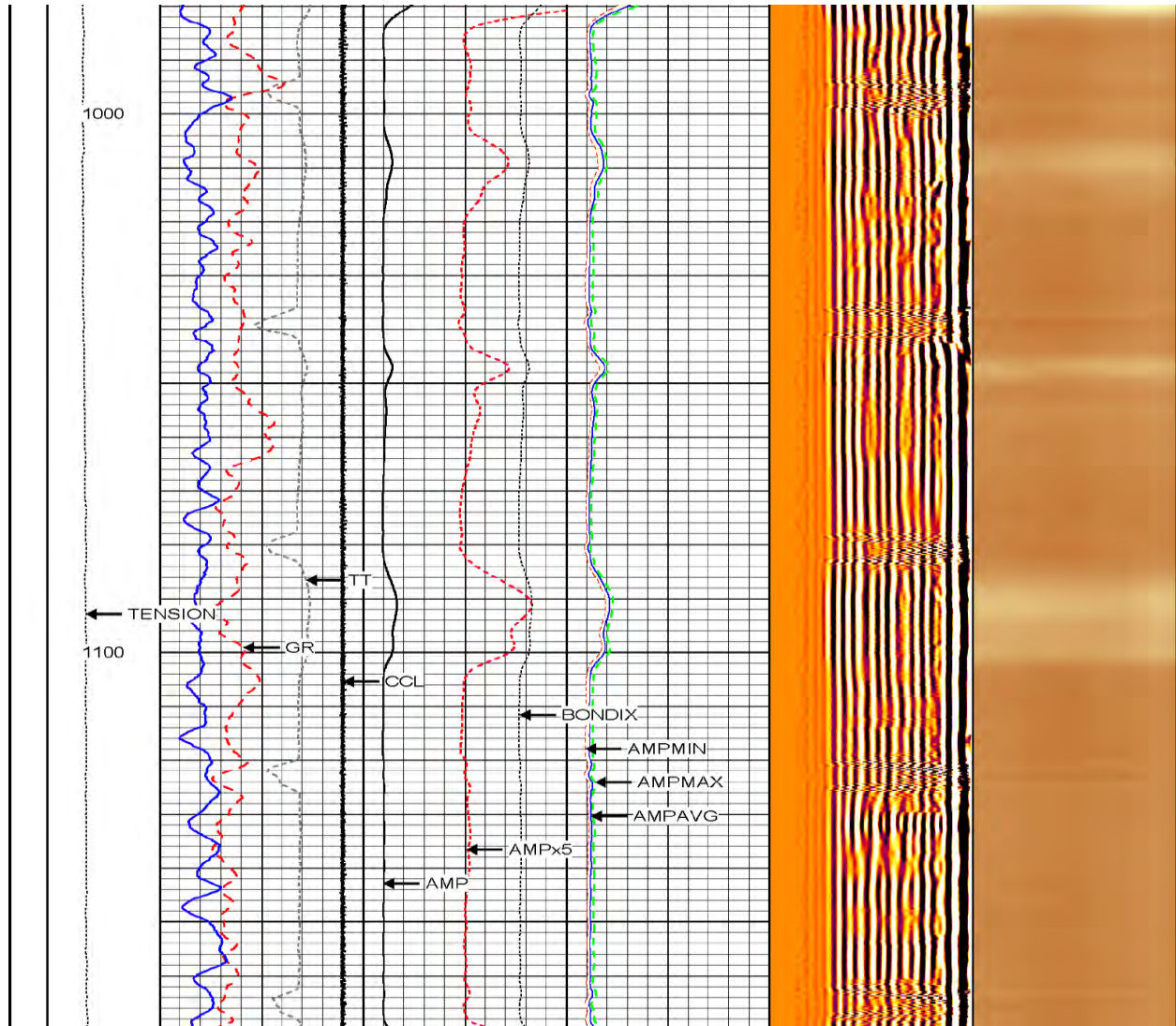


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### Selected Intervals

985 – 1170'



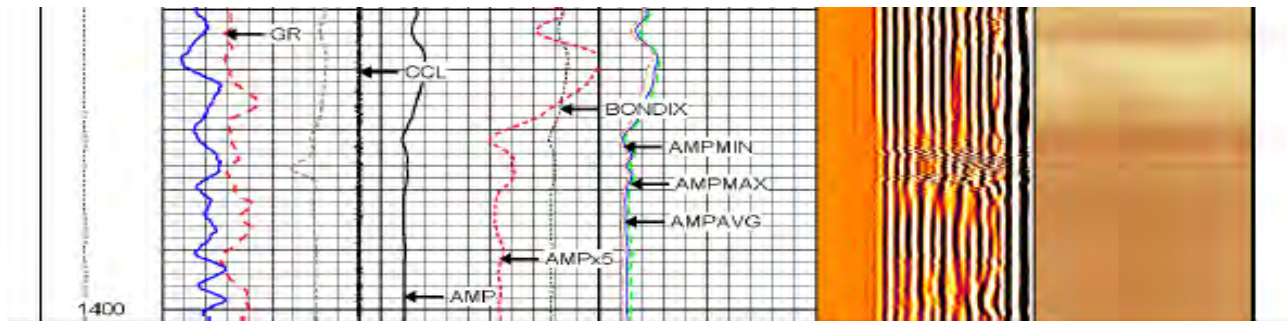
Analysis – Question 1 – Yes there is adequate isolation throughout the section. This section of the wellbore has some microannulus signature as noted by the early arrivals appearing in a “railroad track” configuration as well as the “chevron” appearance at the collar, which is an indicator of decoupling between the pipe and cement, but not between the cement and formation. Areas of consistent better “bond signature” in this section are from 1162-70’, 1134-42’, 1108-12’, 1050-64’, 1014-1030’, 985-1004’. By comparing the poorest in the wellbore section to this interval it is apparent there is much better bonding and much higher probability of an adequate hydraulic seal. We would recommend no remediation effort be conducted as the potential damage to the pipe (perforations) and the cement

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sheath (potential shattering) and the adjacent formation (induced fractures) would potentially have a more deleterious outcome than the current wellbore conditions.

1370 – 1395'



Analysis – Question 1 – There is adequate isolation from top to bottom of the interval. This sector of the well has very uniform response from a bond signal performance perspective. The amplitude curves are consistent across the interval. This section should need no remediation. There are moderately higher amplitudes directly above this section (1310-1370'), but immediately above and below the cement sheath looks to be well contained.



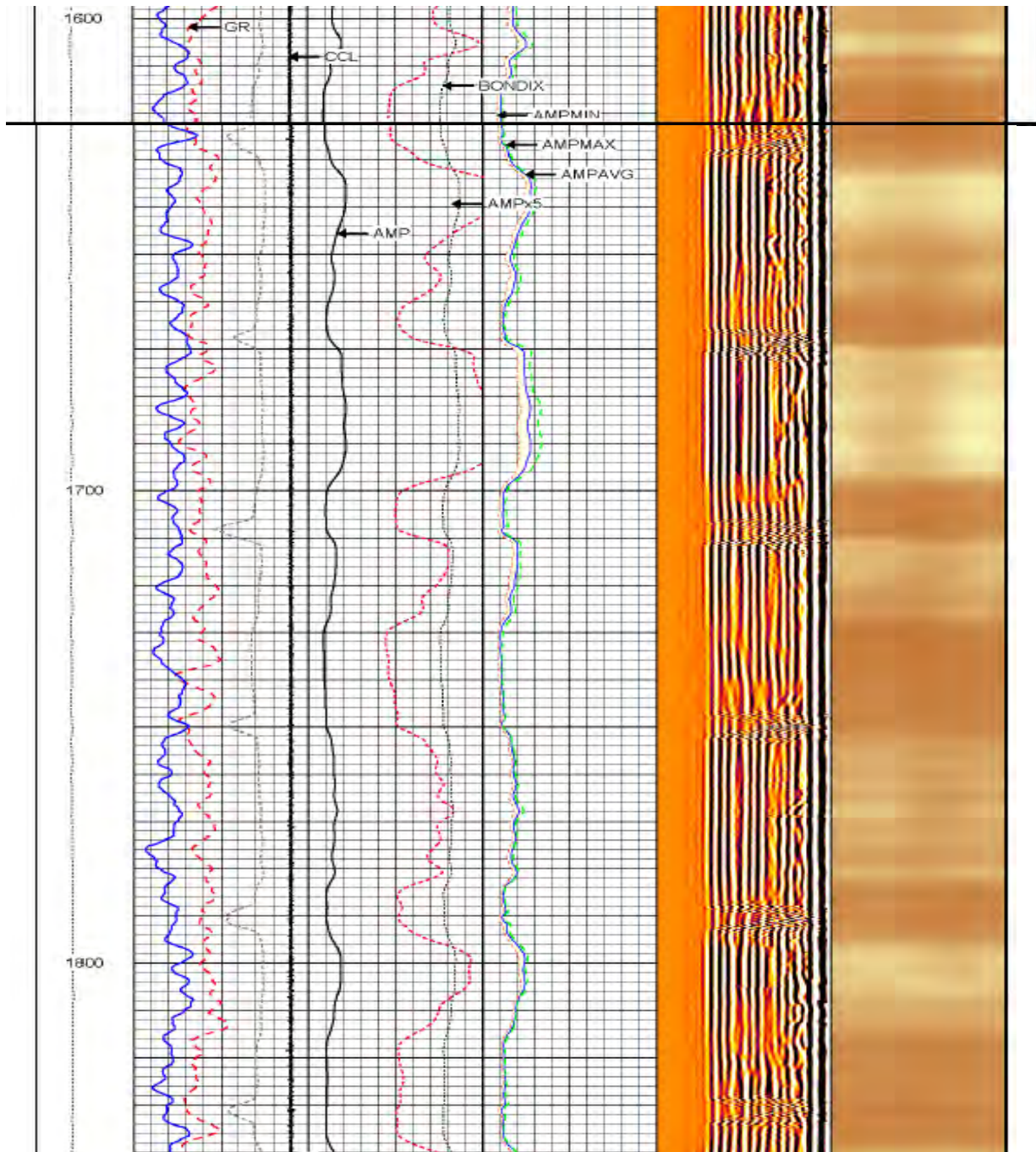
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1618 – 1825'

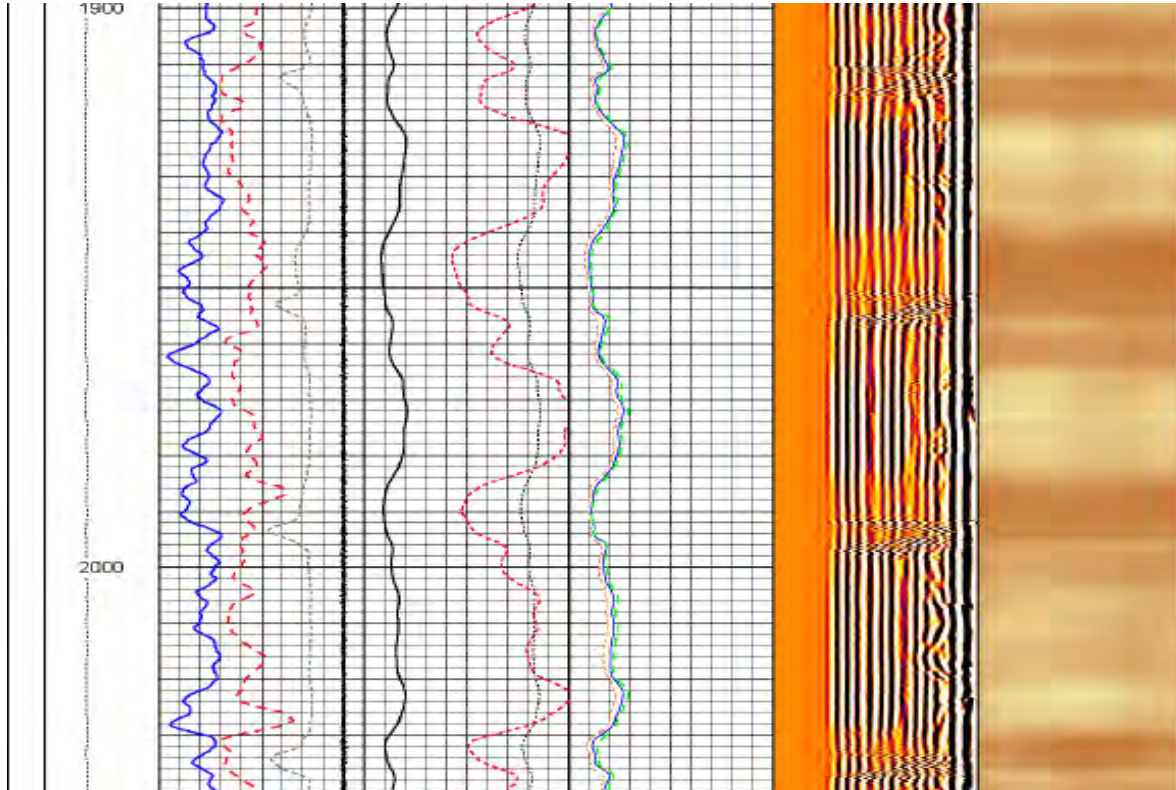


Analysis - Question 1 – Yes, there is adequate isolation from top to bottom of the interval, particularly 1618-30', 1660-68', 1700-10', 1730-50', 1784-93', 1816-36'. We recommend no remedial attempt in this section.

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1935 – 2020'



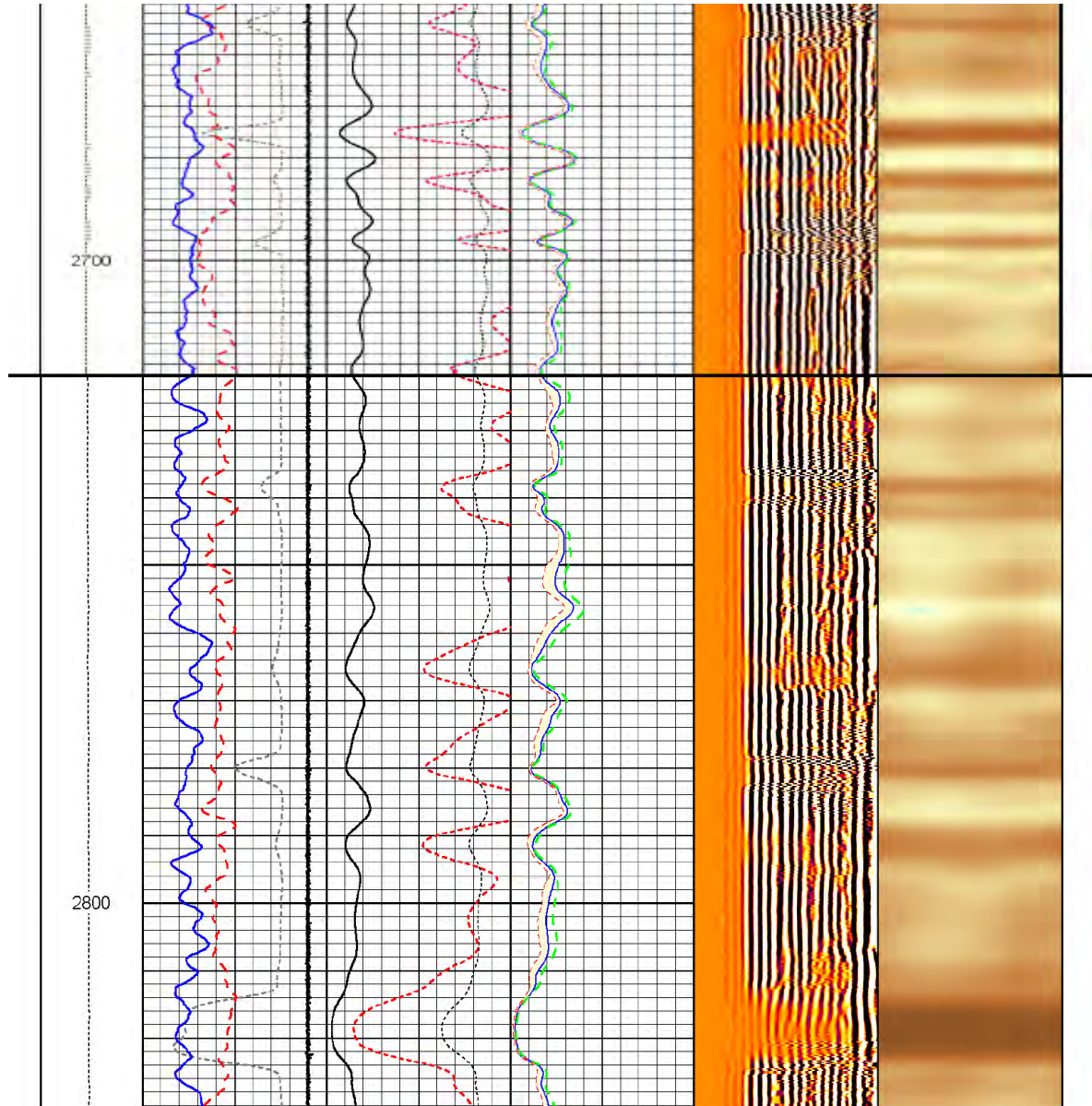
Analysis - Question 1 – Yes, there is adequate isolation from top to bottom of the interval, particularly 1942-54', 1986-94', 2030-34'. We recommend no remedial attempt in this section.

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2650 – 2765'

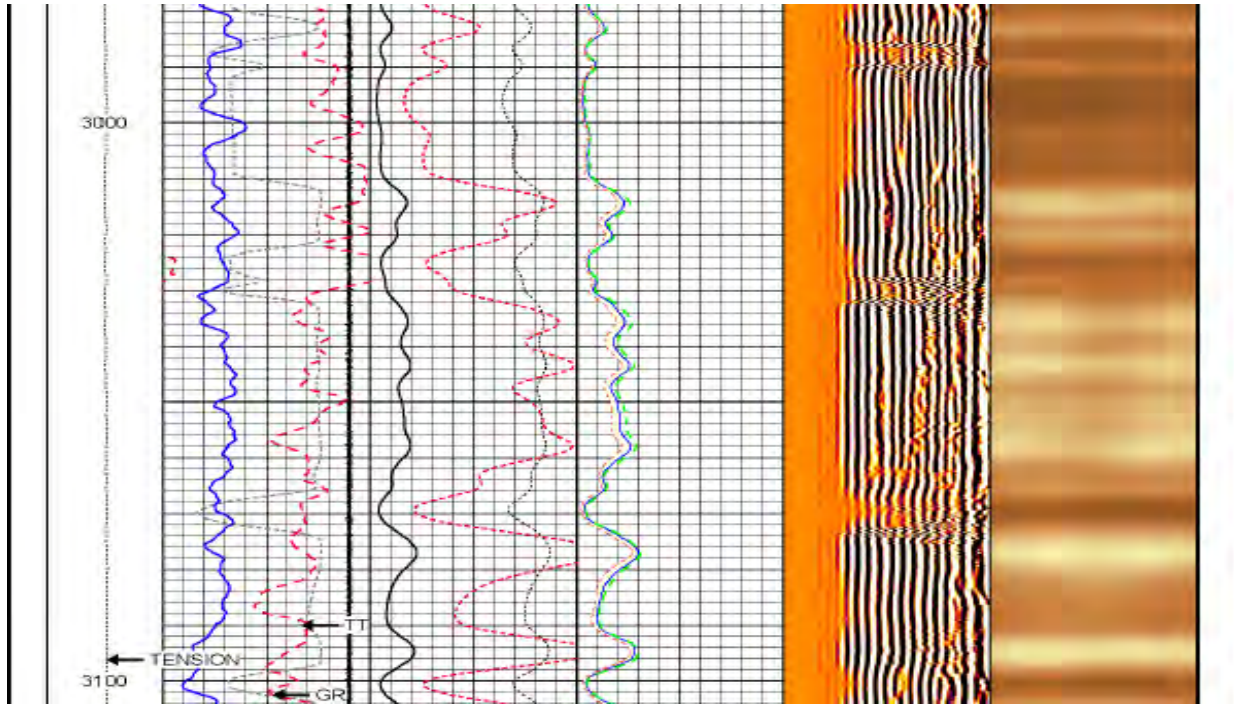


Analysis - Question 1 – Yes, there is adequate isolation from top to bottom of the interval, particularly 2674-76', 2683-85', 2764-66', 2814-24' would most certainly provide a barrier. We recommend no remedial attempt in this section.

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3030 – 3085'



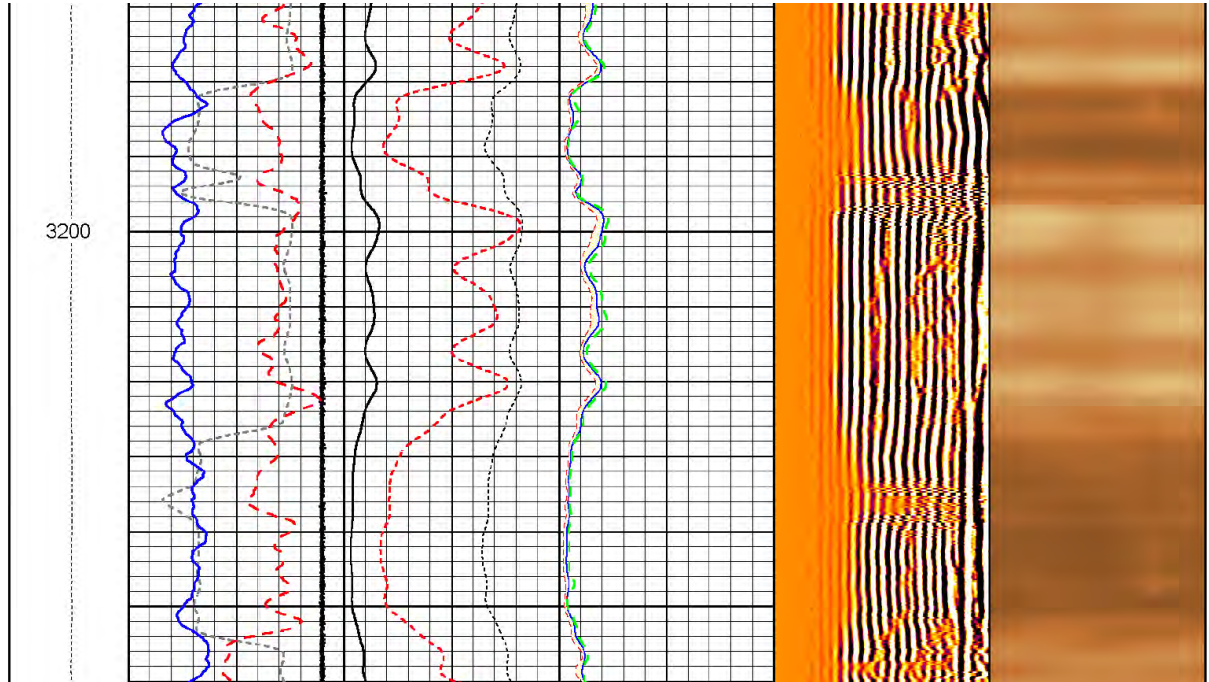
Analysis - Question 1 – Yes, there is adequate isolation from top to bottom of the interval, particularly 3022-32' would provide an upper boundary, 3063-73', 3083-91'. We recommend no remedial attempt in this section.

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3195 – 3255'



Analysis - Question 1 – Yes, there is adequate isolation from top to bottom of the interval, particularly 3180-96', 3204-06', 3215-17', 3222-60'. We recommend no remedial attempt in this section.

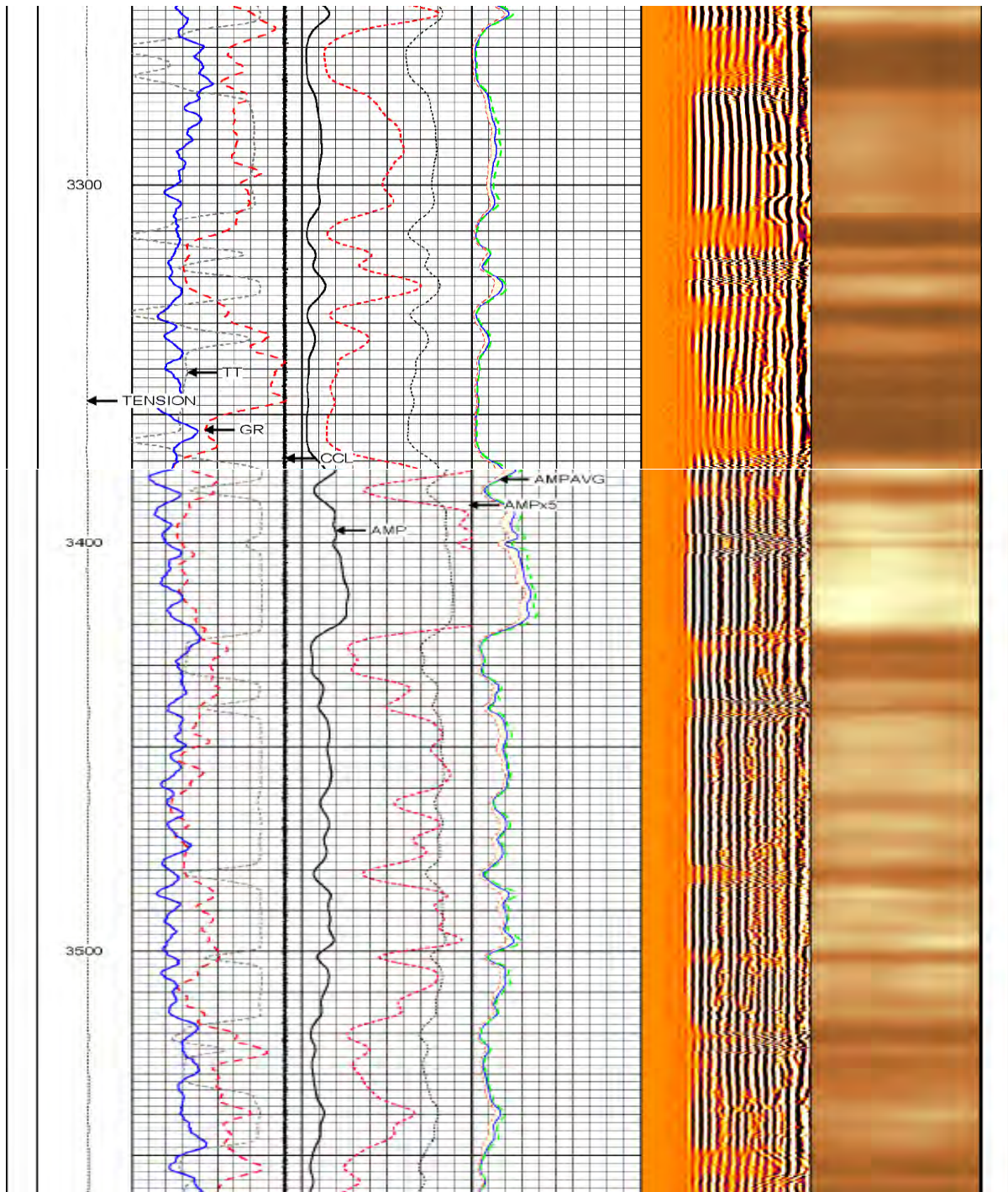
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3265 – 3520'



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Analysis - Question 1 – Yes, there is adequate isolation from top to bottom of the interval, particularly 3265-3320', 3326-60', 3368-78', 3385-89', 3423-34', 3479-83', 3500-3', 3516-37'. We recommend no remedial attempt in this section.

#### Squeeze Comments

Squeeze operations, whether using a cement material or a sealant, require a number of things to occur. First access to the back side of the casing must be established. This is typically accomplished by perforating the pipe by any number of methods. The typical outcome is a hole(s) in the casing, a hole or shattering of the matrix of the existing cement sheath, access to a microannuli if it exists and access to the adjacent formation. Once this communication is established an attempt is made to utilize pressure to “squeeze” a sealant into this complex media. In all situations the sealant is forced into the “path of least resistance”. The least resistant path is most often into the matrix of the formation or into an induced fracture in the formation. You may force a small volume of sealant into a “shattered cement sheath matrix” but these volumes are typically so small, inevitable you fracture or push whole sealant into the formation matrix. The next weakest media in this situation is the cement sheath itself. Microannuli are so small that the pressure required to access them, is always too high (analogous to capillary pressures in porous media) and that leads to failure of the weakest area of access.

Microannulus repair is an exceedingly difficult proposition and through failure to show any significant improvement in the isolational properties of numerous attempts over the years, I would again recommend against any repair effort. The reason for the failure is simply that when you pressurize the interior of the pipe, those forces expand the pipe, pushing the wall against the cement sheath, making it impossible to place sealant in the “micro-void”.

I use the term sealant purposely. Cement slurry is made up of particles with specific sizes. Depending on the product used these particles are large enough that you can't pass it through a 20/40 sand pack (Classes A,B,C,G,H). MicroMatrix cements (and their competitive products) are essentially the fines left over from the grinding processes to make the previously mentioned products. The particle sizes are significantly smaller, but they too will struggle to work through a sand pack, but they do penetrate the pack to some extent. Sealants can be materials such as sodium silicate blends that set due to chemical contact, or designed to have a specific set time. This material forms a gel that depending on make-up would remind you of school “paste”. There are polymeric gels that set into a ringing gel that would remind you of a super ball once set. There are also resins and epoxy that set into very hard, sometimes brittle media. These materials can be pumped as “thinner” fluids than the cement slurries allowing them to invade places/voids cement cannot go.

The likelihood of improving the isolation in any portion of the wellbore is remote at best. The potential for creating flow paths for unwanted fluids is greatly increased by making remediation attempts. Of the materials listed above, only cement would show up on a Cement Bond Log. The other materials could be very effective in filling leaks and voids, were they present, but would not have any effect on a CBL. It is our opinion that none of these materials properly designed and placed would have a positive impact on the isolational properties of the wellbore.

Shawn D. Reed  
VP Operations and Business Development  
CPS, LLC

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